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K. Jaracz

Computing Research of Asynchronous Machine Supplied by Cycloconvertor

ABSTRACT

The simulations results of asynchronous machine supplied by cycloconvertor are main goals of this paper. The transients and principle of operation of cycloconvertor are presented. The paper gives a short survey on control system. All simulation results has been done in MATLAB/Simulink software package.

KEYWORDS: *mathematical model, cycloconvertor, asynchronous machine, thyristor converter, control, MATLAB, Simulink.*

1. INTRODUCTION

The numerical simulation is the best tool to observe the behaviour in transient and steady-state, furthermore enable research new solutions in power electronics and electrical machines.

Semiconductor converters are used more and more frequently to supply induction motors than before. Cycloconvertors are one of the interesting and often used semiconductor converters. This device gives possibility to deliver adjustable frequency voltage to induction motor which has been considered primarily as constant speed machine in the past.

The induction motor has simple construction, reliability, and low cost, has found very wide industrial applications. Nowadays this machines are often used in light and heavy industry. Now the asynchronous machines are finding applications in many areas which previously have been in the domain of the DC machines. This facts are making it necessary to study.

2. ASYNCHRONOUS MACHINE MODEL

The model of the three-phase, induction machine in rotating reference frame (d, q) is represented by electrical and mechanical equations:

$$v_{ds} = R_s i_{ds} + \frac{d\psi_{ds}}{dt} - \omega\psi_{qs}\,,\ v_{qs} = R_s i_{qs} + \frac{d\psi_{qs}}{dt} + \omega\psi_{ds}\,, \tag{1}$$

$$v_{dr} = R_r i_{dr} + \frac{d\psi_{dr}}{dt} - (\omega - \omega_r)\psi_{qr}\,,\ v_{qr} = R_r i_{qr} + \frac{d\psi_{qr}}{dt} + (\omega - \omega_r)\psi_{dr}\,, \tag{2}$$

where

$$\psi_{ds} = L_s i_{ds} + L_m i_{dr}\,,\ \psi_{qs} = L_s i_{qs} + L_m i_{qr}\,, \tag{3}$$

$$\psi_{dr} = L_r i_{dr} + L_m i_{ds}\,,\ \psi_{qr} = L_r i_{qr} + L_m i_{qs}\,, \tag{4}$$

$$L_s = L_{\sigma s} + L_m \,, \tag{5}$$

$$L_r = L_{\sigma r} + L_m \,, \tag{6}$$

$$T_e = 1.5p(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}) \,, \tag{7}$$

and mechanical equation:

$$J \frac{d\omega_m}{dt} = T_e - T_L \,. \tag{8}$$

In the machine equations given above all electrical variables and parameters are referred to the stator. The parameters are defined as follows:

V_{ds}, V_{qs}, - stator voltage refer to d and q axis,
i_{ds}, i_{qs}, - stator current refer to d and q axis,
ψ_{ds}, ψ_{qs}, - stator flux refer to d and q axis,
V_{dr}, V_{qr}, - rotor voltage refer to d and q axis,
i_{dr}, i_{qr}, - rotor current refer to d and q axis,
ψ_{dr}, ψ_{qr}, - rotor flux refer to d and q axis,
R_s, $L_{\sigma s}$, - stator resistance and leakage inductance,
R_r, $L_{\sigma r}$, - rotor resistance and leakage inductance,
L_s, L_r, - total stator and rotor inductance,
L_m - mutual inductance,
T_e - electromagnetic torque,
T_L - load torque,
J - equivalent moment of inertia reduced to the motor shaft,
ω - angular velocity of the frame of references,
ω_r - electrical angular velocity of the rotor,
ω_m - angular velocity of the rotor,
p - number of pole pairs.

3. CYCLOCONVERTOR MODEL

The schematic diagram of the one-phase, six-pulse cycloconvertor is presented in fig. 1. This device is based on two converters A and B, which consists of six power thyristors connected as a bridge. All the system is connected to AC network through transformer T_{rp}.

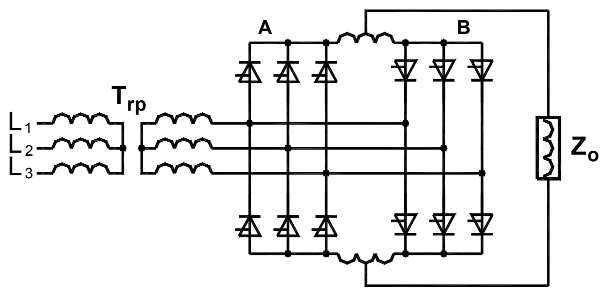

Fig. 1. Schematic diagram of the one-phase, six-pulse cycloconvertor

The control equation of the one-phase, six-pulse cycloconvertor is given by equation [1; 2]:

$$\alpha_A + \alpha_B = \pi \,, \tag{9}$$

where:

α_A, α_B - thyristors gate delay angles, suitably bridge A and B.

When the thyristors gate delay angles α_A and α_B are represented by equations (10), (11), [1; 2] the output voltages are sinusoidal.

$$\alpha_A = \arccos\left(\frac{U_{outm}}{U_{d0}}\sin(2\pi f_{out} t)\right), \tag{10}$$

$$\alpha_B = \arccos\left(-\frac{U_{outm}}{U_{d0}}\sin(2\pi f_{out} t)\right), \tag{11}$$

where:

U_{outm} - maximal output voltage of cycloconvertor,
U_{d0} - maximal output voltage of converter, α=0,
f_{out} - frequency of output voltage,
t - time.

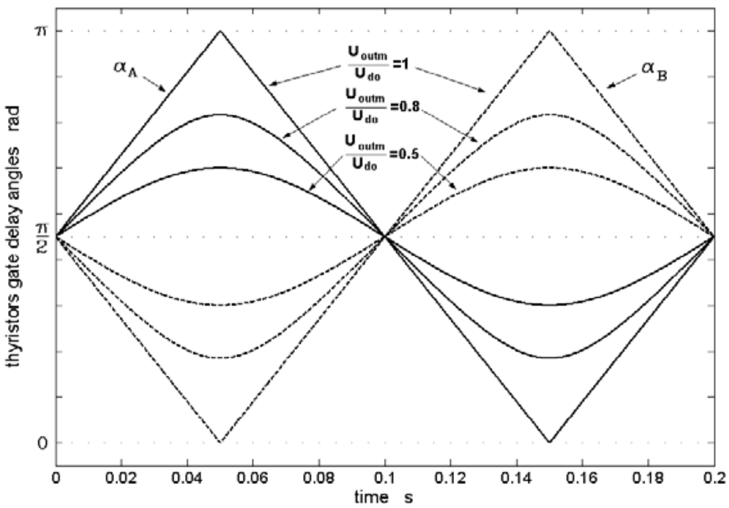

Fig. 2. Transients of α_A and α_B thyristors gate delay angles, f_{out}=5 Hz

Fig. 3. shows schematic diagram of the three-phase, six-pulse cycloconvertor [3] consists of six converters connected to AC network through transformer T_{rp}.

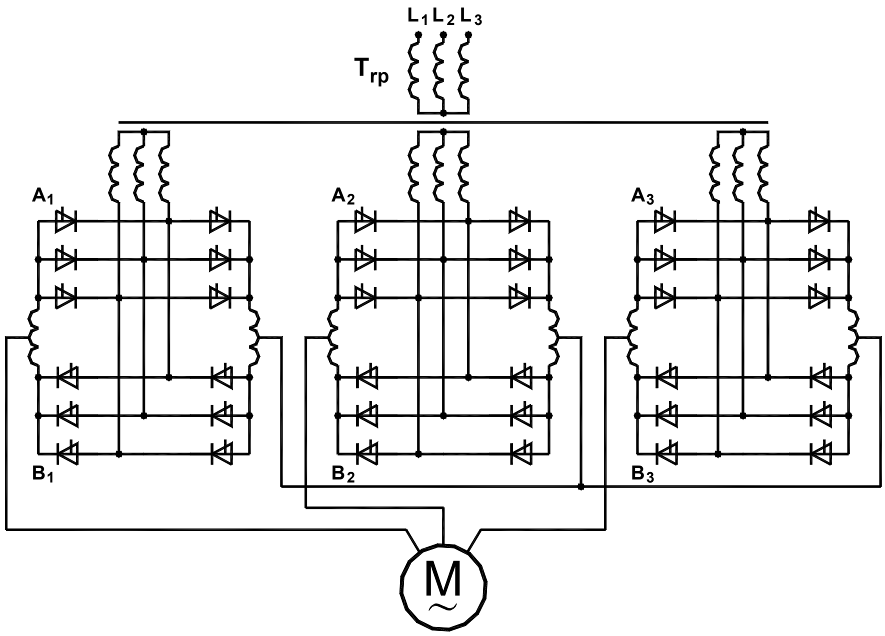

Fig. 3. Schematic diagram of asynchronous machine supplied by the three-phase, six-pulse cycloconvertor

4. SIMULATIONS AND RESULTS OF SIMULATIONS

The transient and steady-state conditions have been modeled by using the MATLAB/Simulink program. Some of simulations results are illustrated in figures 5÷8.

The system studied in this paper is shown in fig. 4. The simulation diagram consists of MATLAB subsystems. The cycloconvertor consists of six converters connected to three separate AC networks. The converters bridges are controlled by synchronized six-pulses generators. All the system directly supply 2 MW asynchronous machine.

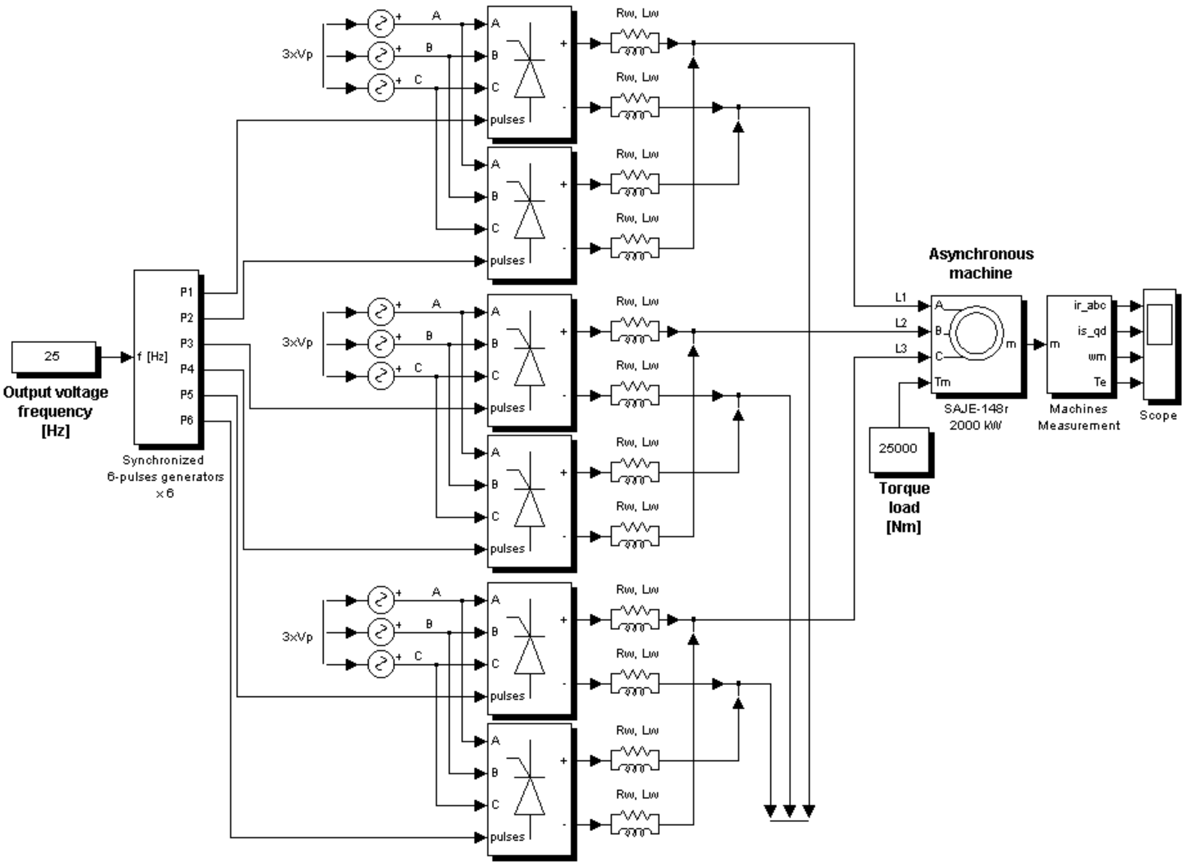

Fig. 4. Block diagram of asynchronous machine supplied by the three-phase, six-pulse cycloconvertor in MATLAB/Simulink software package

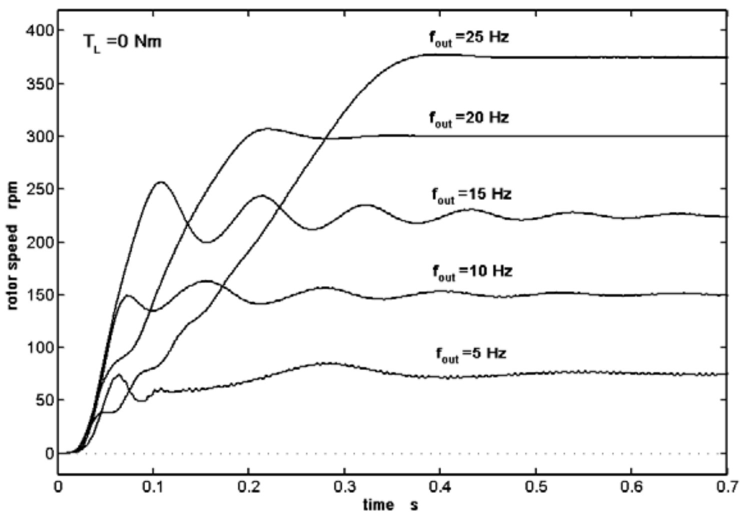

Fig. 5. Transients of rotor speeds, f_{out}=(5÷25) Hz, T_L=0 Nm

Figures 5 and 6 shows rotor speeds with different value of frequency f_{out}=(5÷25) Hz of output voltages.

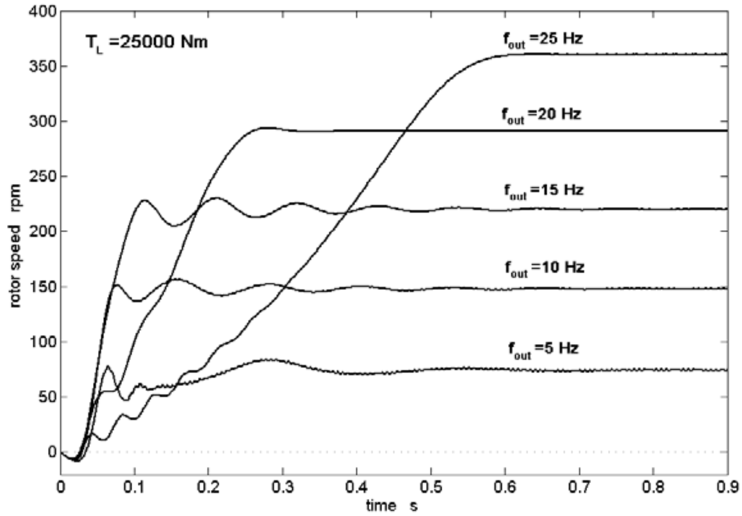

Fig. 6. Transients of rotor speeds, f_{out}=(5÷25) Hz, T_L=25000 Nm

The stator voltages with different value of frequency f_{out}=(5÷25) Hz are illustrated in fig. 7.

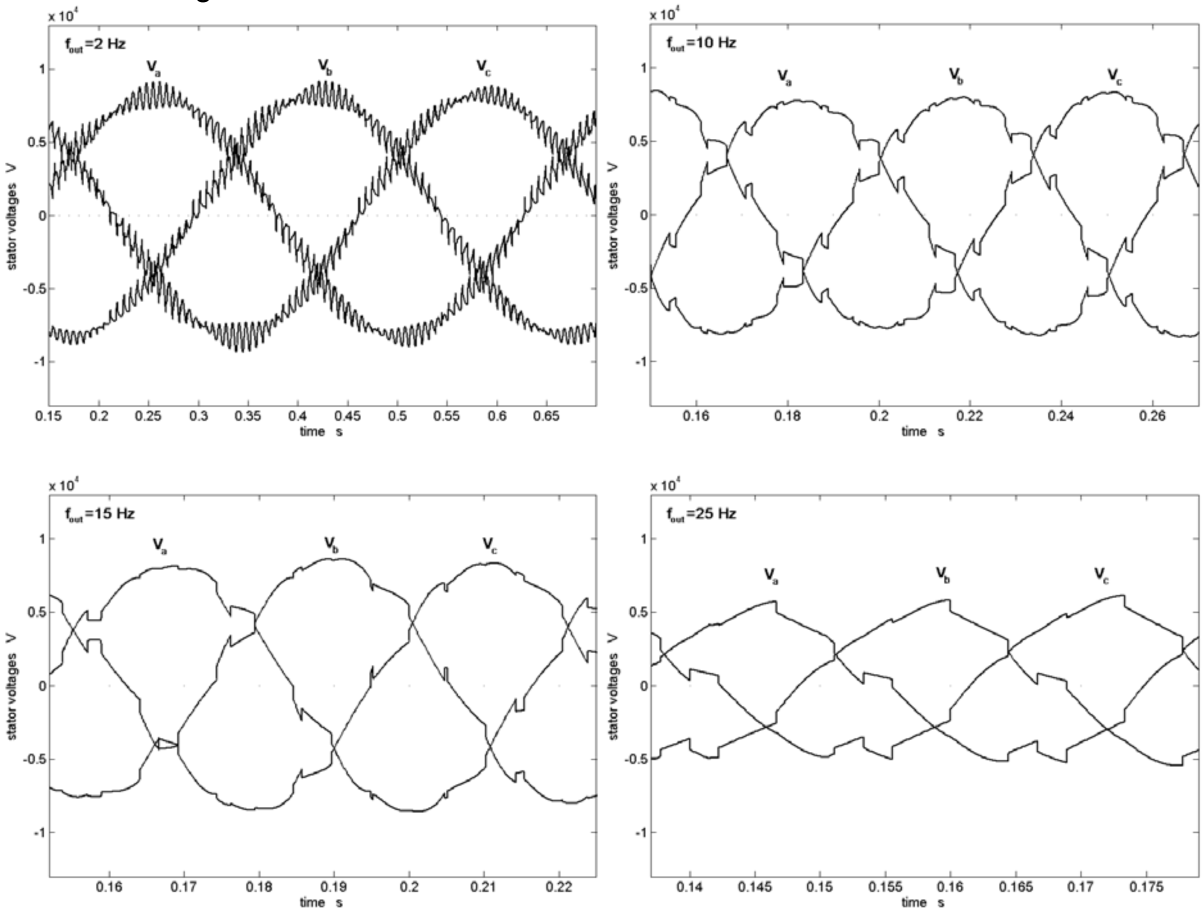

Fig. 7. Transients of stator voltages, f_{out}=(5÷25) Hz, T_L=0 Nm

Transient of rotor speed after step change of rotor speed set value is presented in fig.8.

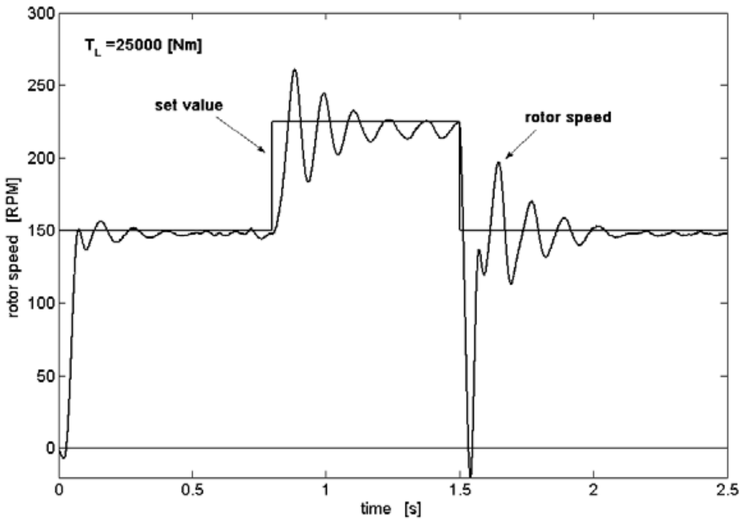

Fig. 8. Transient of rotor speed after step change of rotor speed set value, T_L=25000 Nm

5. DATA MODEL

Numerical analysis is done following parameters:
- asynchronous machine:
P_n=2 MW, V_{nrms}=6000 V, f_n=50 Hz, R_s=1.193 Ω, $L_{\sigma s}$=1,3 mH, R_r=1,168 Ω, $L_{\sigma r}$=1,3 mH, L_m=0.219 H, $J = 525 \ \text{kgm}^2$.
- cycloconvertor:
R_{on}=1 mΩ, L_{on}=0 H, R_s=1 kΩ, C_s=inf F, V_f=0.8 V, L_w=0.05 H, R_w=1 MΩ.
- AC sinusoidal voltage source:
V_p=6285 V, f=50 Hz.

6. CONCLUSIONS

The simulations analysis results of asynchronous machine supplied by cycloconvertor lead the following conclusions:

- presented model gives possibility to study transient and steady-state voltages, currents, angular velocity, and torque of asynchronous machine supplied by cycloconvertor,
- feeding asynchronous machine by cycloconvertor permit to change rotor speed in a wide range,
- the cycloconvertor do not produce pure output voltage sine waves,
- the maximum rotor speed is curtailed due to increasing deformations of output voltages,
- the deformations of output voltages are arising with increasing frequency of output voltages,
- all simulations results of the MATLAB Simulink model confirm the theoretical expectations.

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